The Effect of Hydrogen Saturation on the Phonon Peak in Thermal Conductivity of Superconducting Large Grain Niobium

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Large grain niobium is being developed for construction of future superconducting radio frequency (SRF) accelerator cavities. These cavities operate at $1.8 \leq T \leq 4.5$ K, cooler than the superconducting critical temperature of niobium (9.25 K). Though superconducting, SRF cavities still may have local heat generation arising from surface defect interactions with the radio frequency field. Heat conduction plays a critical role in dissipating the hot spots, making desirable a high thermal conductivity. A phonon peak may occur at about 2 K in the thermal conductivity of Nb, subject to the purity of the metal and its processing history. Deformation and the resulting dislocations in Nb have been shown to reduce the thermal conductivity, especially in the phonon-dominated regime below 3 K. This may explain the performance limitations of the defect-free SRF cavities during their high field operations. The study here considers the effect of interstitial hydrogen on the thermal conductivity near the phonon peak. Thermal conductivity was measured in niobium specimens that had been cut from slices cut from ingots. These specimens were annealed at 1100 C in a high vacuum for two hours prior to initial measurements. This annealing had been shown to produce the maximum available phonon peaks. The specimens were subsequently heated for 1 hr in a 75% H_2 atmosphere at 0.5 atm and 300 C. Calculations indicated that this saturated the 3 mm thick Nb specimens. Subsequent measurements showed that the conductivity at the phonon peak was reduced by about 25%. After heating at 800 C in a high vacuum, the phonon peak only partially recovered. Moreover, a decrease in RRR seems to be due to other than mobile hydrogen that can be degassed. This may indicate the formation of hydrides (or niobium-hydrides) despite the relatively cool 300 C saturating temperature.